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A SENSITIVITY TEST FOR CASTABLE LIQUID EXPLOSIVES
INCLUDING RESULTS FOR SOME NEW MATERIALS

22 OCTOBER 1953



U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

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A SENSITIVITY TEST FOR CASTABLE LIQUID EXPLOSIVES
INCLUDING RESULTS FOR SOME NEW MATERIALS

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ABSTRACT: A new sensitivity test for liquid castable explosives is described. Liquid TNETB, 60/34/6 RDX/TNETB/Wax, TNT, and COMP B are found to be less sensitive to initiation than liquid 50/50 PENTOLITE under the conditions of this test. TNETB is the short designation for trinitroethyl trinitrobutyrate.

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White Oak, Maryland

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Figure 3. Experimental Procedure

Figure 4. Test Arrangement

Figure 5. Arrangement for Establishing Criterion of Fire for Safety Tests

Figure 6. The Criterion of Fire for the Safety Test

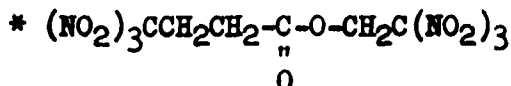
Figure 7. Distortion Produced in Explosive Holder

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A SENSITIVITY TEST FOR CASTABLE LIQUID EXPLOSIVES
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INTRODUCTION

1. TNT, 50/50 Pentolite, and Comp B have been safely melted, handled, and cast for many years. The new explosive TNETB* is now ready for experimental casting. The structural formula of this explosive is:



Some of the important properties^{1,2} of solid TNETB from a safety standpoint have already been determined. The sensitivity of liquid TNETB to various possible methods of accidental initiation has not yet been determined. Certainly it is an impossible task to determine the sensitivity of any explosive to all possible methods of accidental initiation. Consequently it is the restricted purpose of this report to present the results of some small scale sensitivity experiments which order the shock sensitivity of TNT, Comp B, 50/50 Pentolite, TNETB, and 60/34/6 RDX/TNETB/Wax in the liquid state at temperatures between 90°C. and 100°C., the condition of these explosives during ordinary handling while in the liquid state. The experimental arrangement and the procedure used was determined on the basis of past experience with solid explosive shock sensitivity tests and by trial and error and on the basis of convenience. A small scale test was used due to the scarcity of TNETB.

EXPERIMENTAL PROCEDURE

2. Each of the explosives to be tested was placed in a glass beaker which in turn was heated in a boiling water bath (see Figure 1) until the explosive was completely melted. This melted explosive was then allowed to sit in the bath for a time sufficiently long before use,

¹ NavOrd Report 2940, Sensitivity of Explosives to Impact, 1 May 1952 to 1 July 1953, George Svadeba. (To be published)

² NavOrd Report 2614, Evaluation of 2,2,2-Trinitroethyl 4,4,4-Trinitrobutyrate as a Constituent of Castable Explosive, L. D. Hampton and George Svadeba, 30 September 1952.

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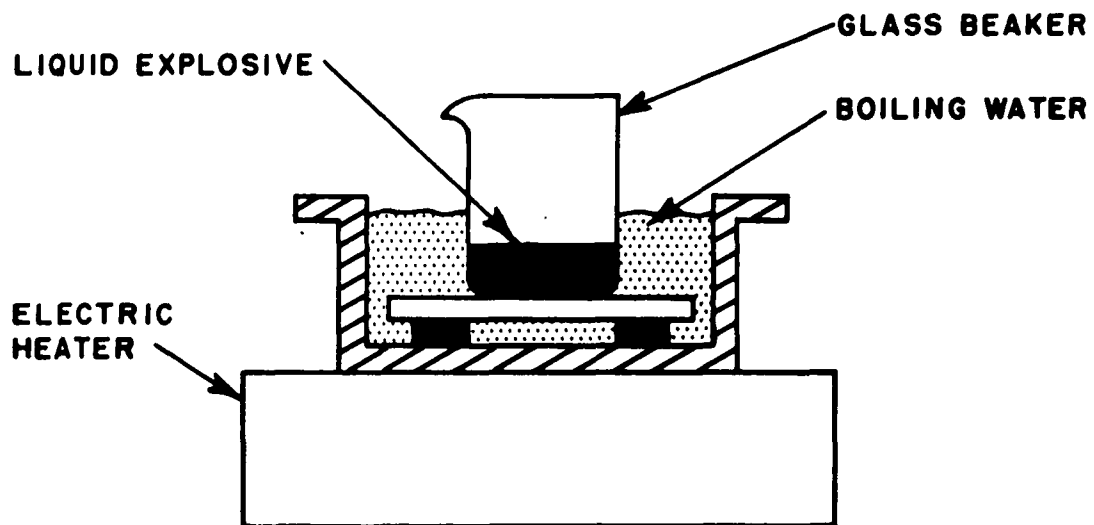


FIG. 1 PREPARATION OF LIQUID EXPLOSIVE

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that it was assumed to have reached a temperature very close to that of the boiling water. In another similar hot water bath the inert materials (the explosive holder and the spacer cylinders (see Figure 2)) were also heated to the temperature of boiling water.

3. The mechanics of the experiment is illustrated in Figure 3. First a special detonator (the donor) consisting of a half inch long cylindrical column of RDX 0.200 inches in diameter, pressed at 10,000 psi into a brass cylinder one inch in outside diameter, and initiated by a special detonator containing about 200 mg of dextrinated lead azide is connected to the firing line ready for immediate use. Then the sample explosive which has been heating in the boiling water bath is poured into the explosive holder as illustrated in Step 3 of Figure 3. The brass air spacers are then quickly dried on blotter paper and still too hot to touch are placed in position on top of the explosive holder as shown in Step 5. The explosive holder with the air spacer in place is now quickly carried (using an insulated tongs) into the firing chamber and set on the cold steel deck. The donor is then placed in position, the chamber door closed, the firing voltage connected to the firing line and the firing switch closed.

4. The time required to complete this action beginning with the removal of the explosive holder and brass spacer from the hot water and ending with the closing of the firing switch was kept fixed. It was found that this action could be done (with only a little practice) in fifteen to twenty seconds. It was decided then to keep this time interval fixed at twenty-five seconds. Assemblies accomplished in a shorter time were allowed to sit until 25 seconds had passed. Whenever fumbling occurred or whenever it was not possible to keep this time interval down to twenty-five seconds, the entire procedure was repeated. This time control was the only convenient method of temperature control available and in some ways is perhaps a very satisfactory control since in the actual casting procedure, no very exact temperature control is maintained during the entire handling process, but rather the liquid explosive is kept at a temperature only slightly above the melting point.

5. As a further check upon the temperature it was determined that liquid TNT as obtained by the procedure through Step 5 when allowed to sit on the cold steel firing chamber deck as shown in Step 6, showed no signs of crystallization after two minutes of cooling. While some of the other explosives showed signs of freezing in times of the order of a half minute, this was only surface freezing and the temperature of the explosive as a whole was not far from the melting point. This

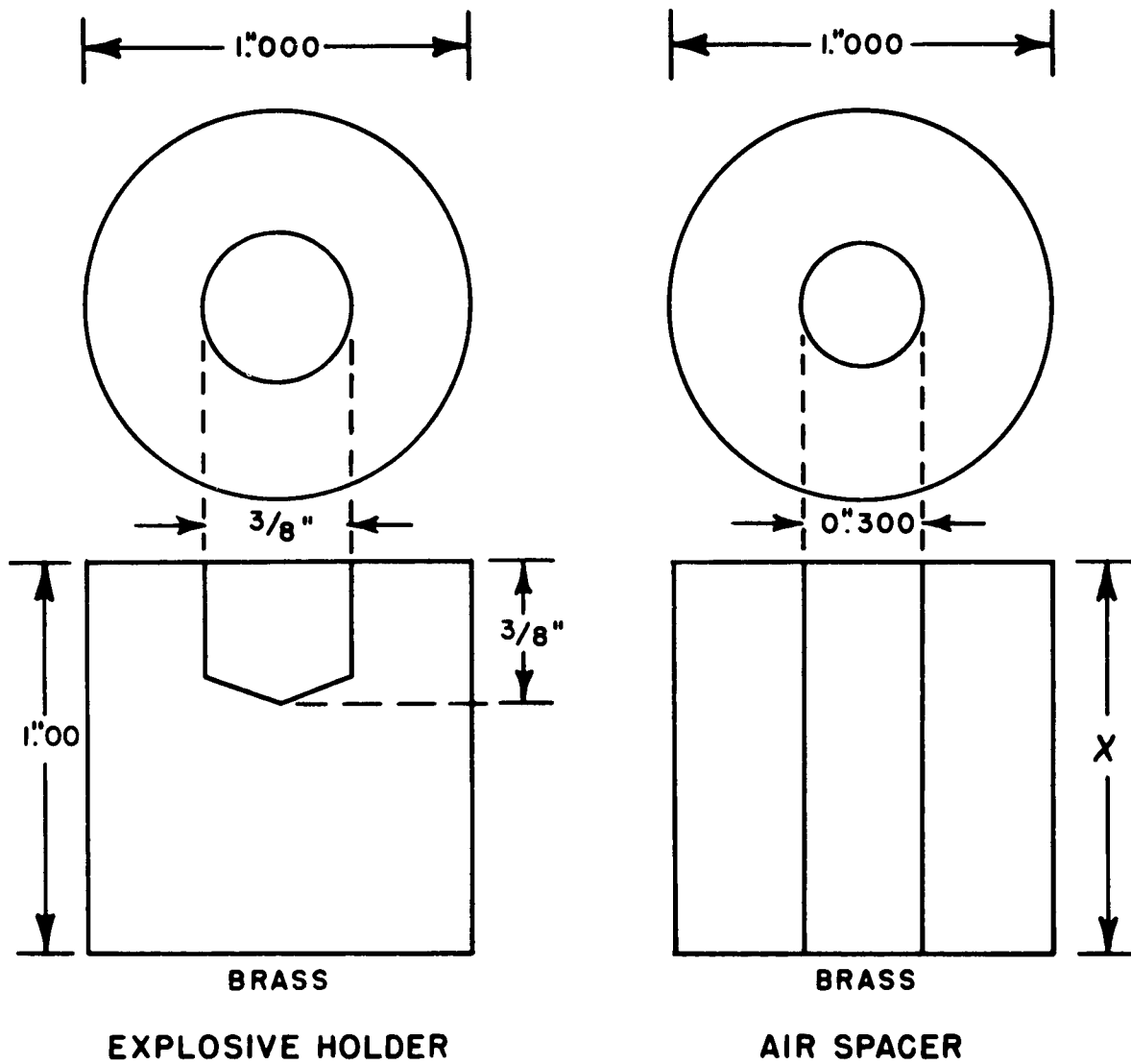
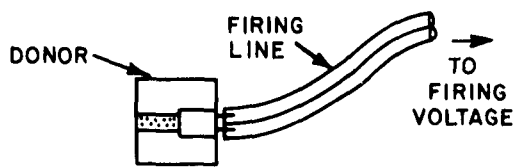
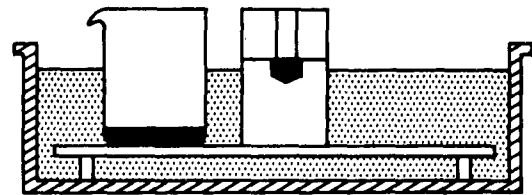


FIG. 2 INERT MATERIALS

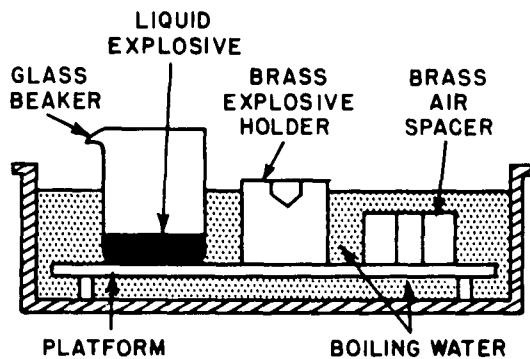
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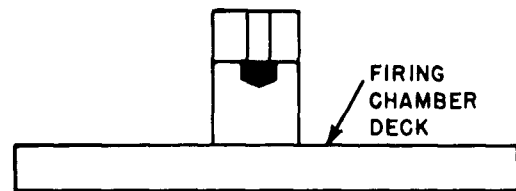
STEP 1 CONNECT DONOR TO FIRING LINE



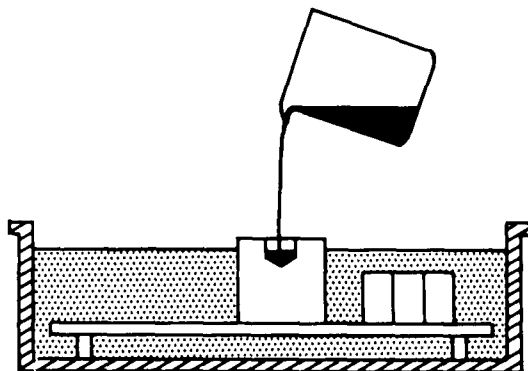
STEP 5 ALIGN EXPLOSIVE HOLDER AND SPACERS



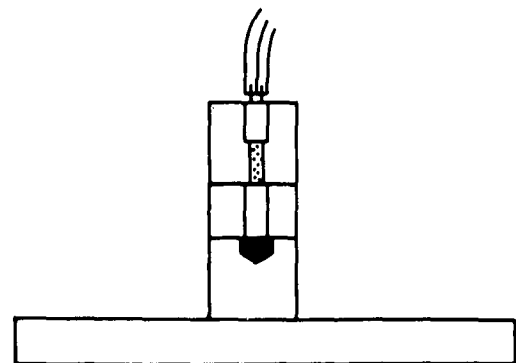
STEP 2 HEAT EXPLOSIVE AND INERT COMPONENTS



STEP 6 PLACE EXPLOSIVE HOLDER AND SPACER IN FIRING CHAMBER



STEP 3 FILL EXPLOSIVE HOLDER WITH LIQUID EXPLOSIVE



STEP 7 PLACE DONOR IN POSITION

(SEE FIG. 4 FOR DONOR DETAILS)



STEP 4 DRY AIR SPACERS

FIG. 3 EXPERIMENTAL PROCEDURE
(TIME INTERVAL BETWEEN STEP 5 AND FIRING OF DONOR = 25 SECONDS)

again is the situation in melting and casting practice where surface freezing is almost always somewhere to be observed. We were able then, with the procedure described above, to make a shock sensitivity examination of the five castable explosives under consideration when each of the explosives was at various temperatures between their melting point temperatures and 100°C. Due to the time control previously mentioned this temperature control was probably such that the temperatures of all of these explosives at the time of firing was between 90°C. and 100°C. and probably very close to the lower bound, i.e., perhaps 92 or 93 degrees.

6. A Bruceton type test³ was used to compare the sensitivities of the five liquid explosives under consideration. The donor, the air spacer, and the explosive holder are in the position shown in Figure 4 during firing. The length, x , of the air spacer is varied from shot to shot in increments of $1/8$ inch. The diameter of the cylindrical air space is kept fixed at 0.300 inches. When for a particular length, x , of the air gap, it is observed that the explosive sample in the explosive holder has been initiated in accordance with a particular criterion to be discussed later, the next shot is made using an air gap equal to $x + 1/8$ inch. If the sample explosive fails to be initiated according to this criterion then the next shot is made using an air gap equal to $x - 1/8$ inch. In this way the air gap for which the donor used was able to initiate the sample explosive in accordance with the chosen criterion of fire with 50% reliability was found for each of the five explosive samples tested.

SOME IMPORTANT CONSIDERATIONS

7. Let us recall that the test just described is primarily designed to be a safety test applicable to the handling of large quantities of liquid TNETB and 60/34/6 RDX/TNETB/Wax which are at temperatures very close to their respective melting points. For TNT, Pentolite, and Comp B, safe procedures have been developed and are now in use. Recent impact sensitivity tests¹ of these explosives show that for the granulated solid materials, heights of 160, 60, and 38 centimeters respectively are required for the 50% certainty of initiation of TNT, Comp B and 50/50 Pentolite by a 2.500 kg weight. For TNETB and 60/34/6 RDX/TNETB/Wax, heights of 18 and 65 centimeters respectively were obtained. If these numbers are applicable also for ordering the sensitivity of the

³AMP Report 101.1R, Statistical Analysis for New Procedure in Sensitivity Experiments.

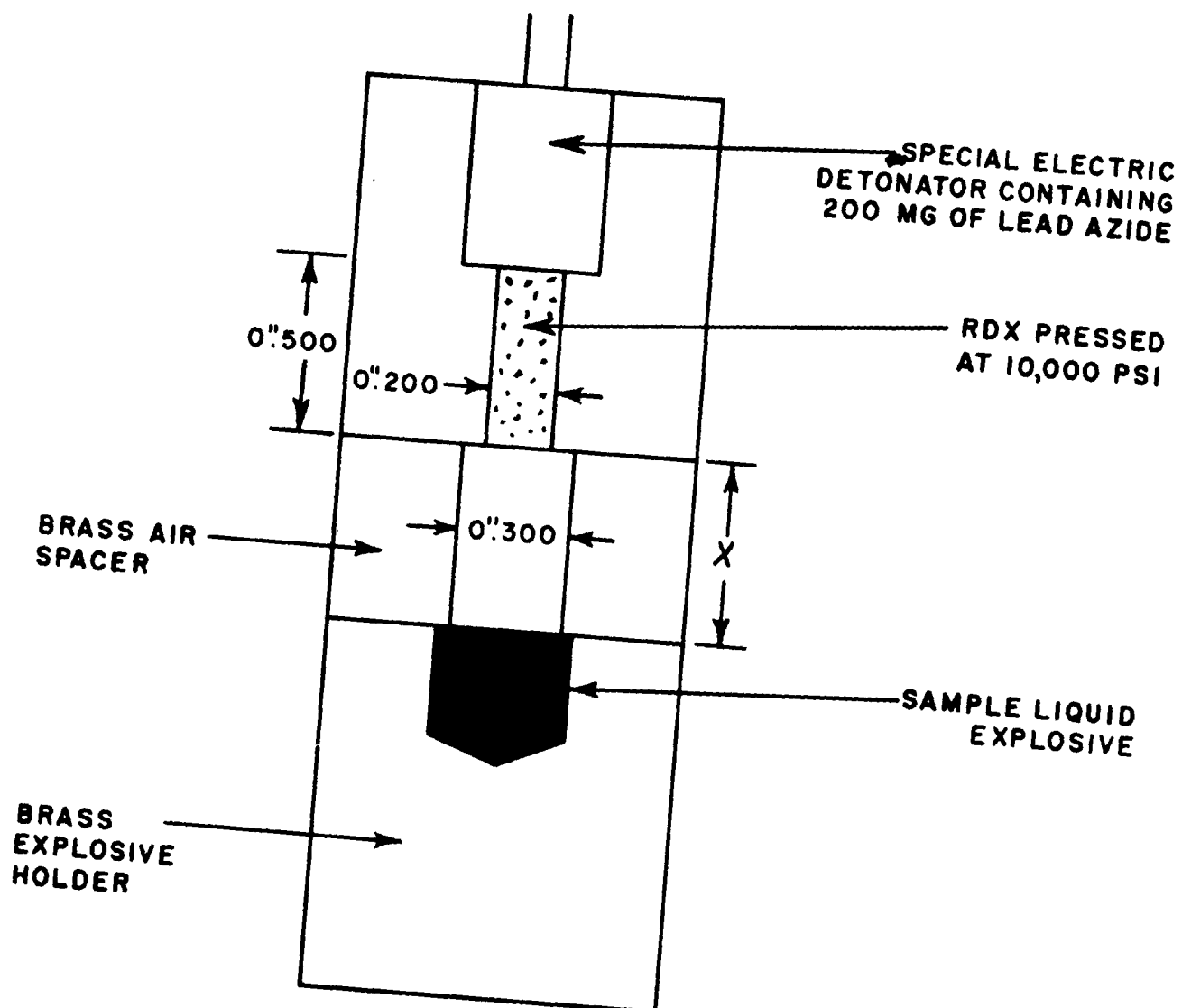


FIG. 4 TEST ARRANGEMENT

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explosive in the liquid state then it would appear that the operating procedure already in use should be sufficiently safe for handling and casting 60/34/6 RDX/TNETB/Wax, but perhaps not good enough for pure TNETB.

8. The question as to whether the order of sensitivity of the liquid explosive is different from the solid is all important. That the order of sensitivity can be different is obvious even if the ordering were independent of the explosives environment. It is well known, for example, that there is no way of insuring that the order of sensitivity to initiation of any series of explosives in any state will remain unchanged when we change such apparently insignificant things as particle size, geometry or confinement. When we change both state and environment we are on even less sure ground. The sensitivity results to be presented here then, while probably more nearly applicable to the handling of liquid explosives than the impact sensitivity tests on the solid explosives, should nevertheless be used only with the utmost caution for it is well known that another important factor in sensitivity is the amount of explosive involved. A gentle reaction begun in a small amount of explosive may never grow to be a vigorous one only because there was not enough explosive material for the reaction to build up to its maximum vigor. Conversely we may be further misled by the fact that a gentle reaction begun in a small amount of explosive may be observed as a self propagating reaction when in reality if there had been more explosive the reaction would have eventually died out due to the dissipation of reaction energy into the area surrounding the reaction. The build up and propagation of the reaction in an explosive system are thus intimately connected with the apparent sensitivity of the explosive and a careful complete study of sensitivity should include a study of build up and propagation. To be on the safe side, however, in a safety test we will welcome those errors which show any unknown explosive more sensitive than it really is, that is, we will accept those reactions as fires which would die out in a large quantity of explosive, but which look like fires in a small amount of explosive.

THE CRITERION OF FIRE

9. We need, then, a criterion of fire which for our small scale test will be clearly able to distinguish a reaction from no reaction and which at the same time will be able to distinguish only a very gentle reaction from no reaction.

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10. It was decided with all of these considerations in mind to use as the criteria of fire in this safety test an amount of damage to the explosive holder only slightly greater than that produced by the firing of the donor directly in contact with the explosive holder containing an inert liquid. For this purpose several inert liquids (water, Esterline Angus ink, Coca Cola, and carbon tetrachloride) were used.

11. The inert liquid was used to fill the cavity of the explosive holder. The donor was then placed directly in contact with the explosive (see Figure 5) and fired. The distortion of the $3/8$ inch drill hole in the explosive holder was such that for all of these liquids it was just possible to fit the shank of a $15/32$ inch drill into the enlarged hole. A $31/64$ inch drill shank would fit in none of these distorted holes. The criterion of fire for the safety test was consequently chosen as follows. Any shot of the test which produced a distortion of the explosive holder cavity great enough so that a $31/64$ inch drill shank would fit into it was called a fire. If the drill shank could not be forced into this cavity using only a moderate hand push, the shot was called a misfire. In Figure 6 a typical fire and a typical misfire for all of the explosives of this safety test are shown. The distortion produced by a typical high order detonation of any of the explosives of these tests is shown in Figure 7. As already pointed out, however, we do not require such high order fires in our safety test.

RESULTS AND SOME WORDS OF CAUTION

12. The results of the safety test are shown in Table I. If these numbers are applicable for ordering the sensitivities of the five castable explosives then it would appear that the operating procedures already in use for the handling of Pentolite in the liquid state should also be satisfactory for the safe handling of liquid TNETB and 60/34/6 RDX/TNETB/Wax.

13. There is good reason for the uncertainty of the above paragraph. Firstly, as already mentioned there is no certainty that the order of sensitivity of the explosives examined in this test is independent of environment. In the casting house much larger quantities of explosive are handled under conditions of confinement much different from those of the test. In general, these conditions are likely to provide poorer confinement and consequently greater safety for any particular explosive, but this does not insure that the order of sensitivity which is our chief concern here remains unchanged. For example, ⁴barrier tests indicate

⁴NavOrd 2494, A Small Scale Gap Sensitivity Test, W. E. Dimmock, Jr., 2 July 1952.

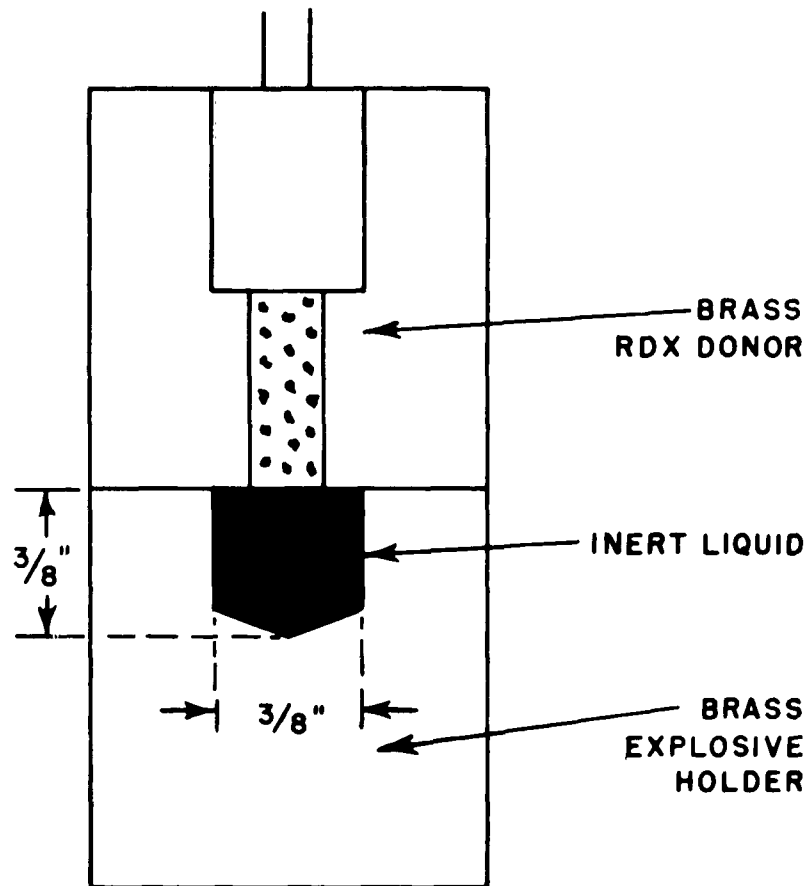


FIG. 5 ARRANGEMENT FOR ESTABLISHING CRITERION
OF FIRE FOR SAFETY TEST

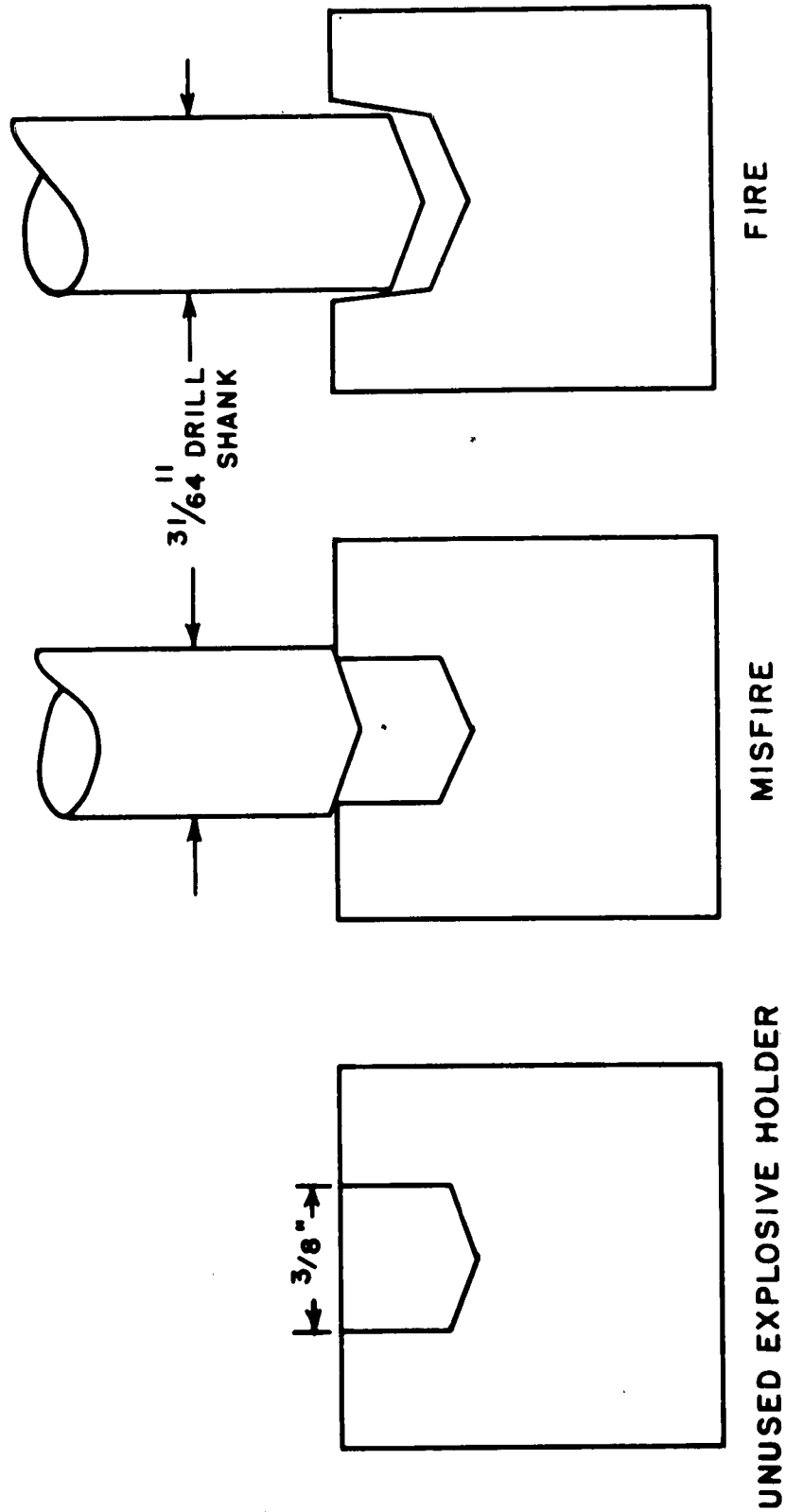


FIG. 6 THE CRITERION OF FIRE FOR THE SAFETY TEST
(SHOWING AN UNUSED EXPLOSIVE HOLDER AND THE DISTORTION
PRODUCED BY A TYPICAL MISFIRE AND A TYPICAL FIRE)

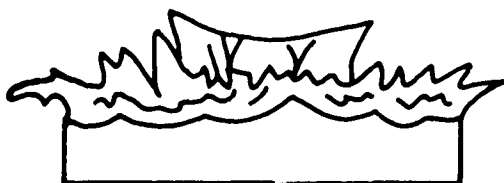


FIG. 7 DISTORTION PRODUCED IN EXPLOSIVE HOLDER
BY A TYPICAL HIGH ORDER DETONATION OF THE SAMPLE EXPLOSIVES
UNDER TEST

TABLE I. BRUCETON SAFETY TEST RESULTS FOR FIVE CASTABLE EXPLOSIVES. The means and the standard deviations of the means of the lengths of the 0.300 inch diameter cylindrical holes across which initiation of the liquid castable explosive is possible for the system of Figure 4 with 50% certainty are underlined in the tabulation.

Length of air gap (inches)	TNT No. of Fires Misfires	COMP B No. of Fires Misfires	PENTOLITE No. of Fires Misfires	TNETB No. of Fires Misfires	^{60/34/6} RDX/TNETB/WAX No. of Fires Misfires
0.000					
0.125	1 0	1 0			
0.250	8 1	5 1			
0.375	5 7	5 4			
0.500	<u>0.391 ± 0.040</u> 3 5	<u>0.381 ± 0.042</u> 1 5			
0.625	0 3	0 1			2 0
0.750	- -	- -	- -	- -	8 2
0.875	- -	- -	- -	- -	<u>0.588 ± 0.026</u> 5 8
1.000	- -	- -	1 0	<u>0.920 ± 0.059</u> 2 6	0 5
1.125	- -	- -	4 1	1 2	
1.250	- -	- -	6 5	0 1	
1.375	- -	- -	<u>1.295 ± 0.052</u> 2 6		
1.500	- -	- -	1 2		
1.625	- -	- -	0 1		

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that the orders of sensitivities of pressed granular RDX and Tetryl, and of Comp A and TNT are reversed when the confining media for these explosives are changed from brass to aluminum. Also as already mentioned the amount of explosive handled has an effect upon the apparent sensitivity. While this might tend to increase the sensitivity of any particular explosive there is again no certainty that the order of sensitivity will remain unchanged.

14. The chief difficulty, however, is that found in any safety test. The criterion of fire must be chosen arbitrarily. This has to do with the general nature of the initiation of explosives. There is no sharp dividing line between fires and misfires. Unpublished experiments of a preliminary nature indicate that there is more to the vigor of initiation than the simple high order and low order picture prevalent in most of the literature. There are various grades and shadings of high and low orders of initiation and these depend upon the explosive under consideration as well as upon the method of initiation.

15. One difficulty that is insurmountable is that the way in which any explosive will build up to its maximum vigor is dependent upon the method and mechanism of the initiation. When we attempt, then, to apply any safety test or any series of safety tests to a group of explosives we must consider all of the various possible methods of initiation as well as all of the various degrees of vigor of initiation of all of these various methods under all of the various conditions of handling. This means that we must perform a series of safety tests in which we choose many different criteria of fire. We must even consider the various ways in which for example, one might drop some of the explosive on the floor. Clearly it is impossible to conceive of all of these possibilities let alone test the order of sensitivity of a series of explosives to all of these possible methods of initiation.

16. One can safely say, however, that if in any test at all, any mechanism of initiation which is not impossible under the proposed handling procedure shows a particular explosive to be more sensitive than any of those explosives already safely handled that this is sufficient grounds for caution. And furthermore, further special precautions should be taken to make initiation of the type which shows the unusual sensitivity impossible. The results of the test reported here are by no means sufficient grounds for complacency. For example, if in spite of the results reported here it should be found that TNETB or 60/34/6 RDX/TNETB/Wax show greater sensitivity to friction or static electrical discharge than the most sensitive of those explosives already

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safely handled, then a further examination should be undertaken of the handling procedures in use to further minimize the danger of accidental initiation by these agencies.

17. In line with the thoughts expressed above some further tests were performed in which the criterion of fire was more severe. It was required that a shot be called a misfire unless the explosive holder was shattered in the manner illustrated in Figure 7. In this way it might be possible to judge whether the order of sensitivities changed appreciably when we severely changed the criterion of fire. The results of this test are shown in Table II.

18. An inspection of Tables I and II indicates that there is no appreciable change in the order of sensitivity of these explosives. In particular it is clear that TNETB and 60/34/6 RDX/TNETB/Wax show themselves to be less sensitive than 50/50 Pentolite for both criteria of fire used. Furthermore, it is clear that the differences in sensitivity between these explosives and Pentolite is greater for that criteria of fire which requires the least amount of distortion of the explosive holder. It is not unreasonable then to suppose that for a criterion of fire of even less distortion of the explosive holder than for our safety test (see Figure 6) that the order of sensitivity would be at least as favorable as observed. It can be said with certainty that this test does not indicate that there are any special problems to be encountered in the handling of liquid TNETB or 60/34/6 RDX/TNETB/Wax if the present safety procedures used in the handling of liquid 50/50 Pentolite are observed.

A RECOMMENDATION

19. It is clear that the chances are very good that the order of sensitivity of almost any two explosives can be changed if one performs a large enough number of safety tests and if one uses a large enough number of criteria of fire. It is recommended that this be given greater emphasis in future sensitivity tests. It should, furthermore, be clear that the most meaningful sensitivity test is one in which the growth or decay of the initial reaction can be observed. Initiation of a small harmless reaction that cannot propagate should not be classed as a fire and is no hazard.

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TABLE II. NUMBER OF HIGH ORDER FIRES DIVIDED BY TOTAL NUMBER OF SHOTS

Length of air gap (inches)	TNETB	TNT	PENTOLITE	COMP B	60/34/6 RDX/TNETB/WAX
0.000	7/7	0/8		2/2	3/3
0.125	0/8			0/2	0/2
0.250	3/13		1/1		
0.375	0/3		4/5		
0.500			0/4		